US010626925B2

(12) United States Patent
Boniface

(10) **Patent No.: US 10,626,925 B2**
(45) **Date of Patent: Apr. 21, 2020**

(54) **GAS TURBINE ENGINE WITH A GEARED TURBOFAN ARRANGEMENT**

(71) Applicant: **Rolls-Royce Deutschland Ltd & Co KG**, Blankenfelde-Mahlow (DE)

(72) Inventor: **Dominic Boniface**, Berlin (DE)

(73) Assignee: **ROLLS-ROYCE DEUTSCHLAND LTD & CO KG**, Blankenfelde-Mahlow (DE)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 299 days.

(21) Appl. No.: **15/707,471**

(22) Filed: **Sep. 18, 2017**

(65) **Prior Publication Data**

US 2018/0080504 A1 Mar. 22, 2018

(30) **Foreign Application Priority Data**

Sep. 20, 2016 (EP) 16189697

(51) **Int. Cl.**
F16D 9/06 (2006.01)
F01D 21/04 (2006.01)
(Continued)

(52) **U.S. Cl.**
CPC ***F16D 9/06*** (2013.01); ***B64D 35/02*** (2013.01); ***F01D 15/12*** (2013.01); ***F01D 21/045*** (2013.01);
(Continued)

(58) **Field of Classification Search**
CPC B64D 35/02; F01D 15/12; F01D 21/045; F01D 21/14; F02C 7/36; F02K 3/06;
(Continued)

(56) **References Cited**

U.S. PATENT DOCUMENTS

3,997,042 A 12/1976 Langham
4,270,408 A 6/1981 Wagner
(Continued)

FOREIGN PATENT DOCUMENTS

DE 102011084360 A1 4/2013
EP 2199568 A2 6/2010
(Continued)

OTHER PUBLICATIONS

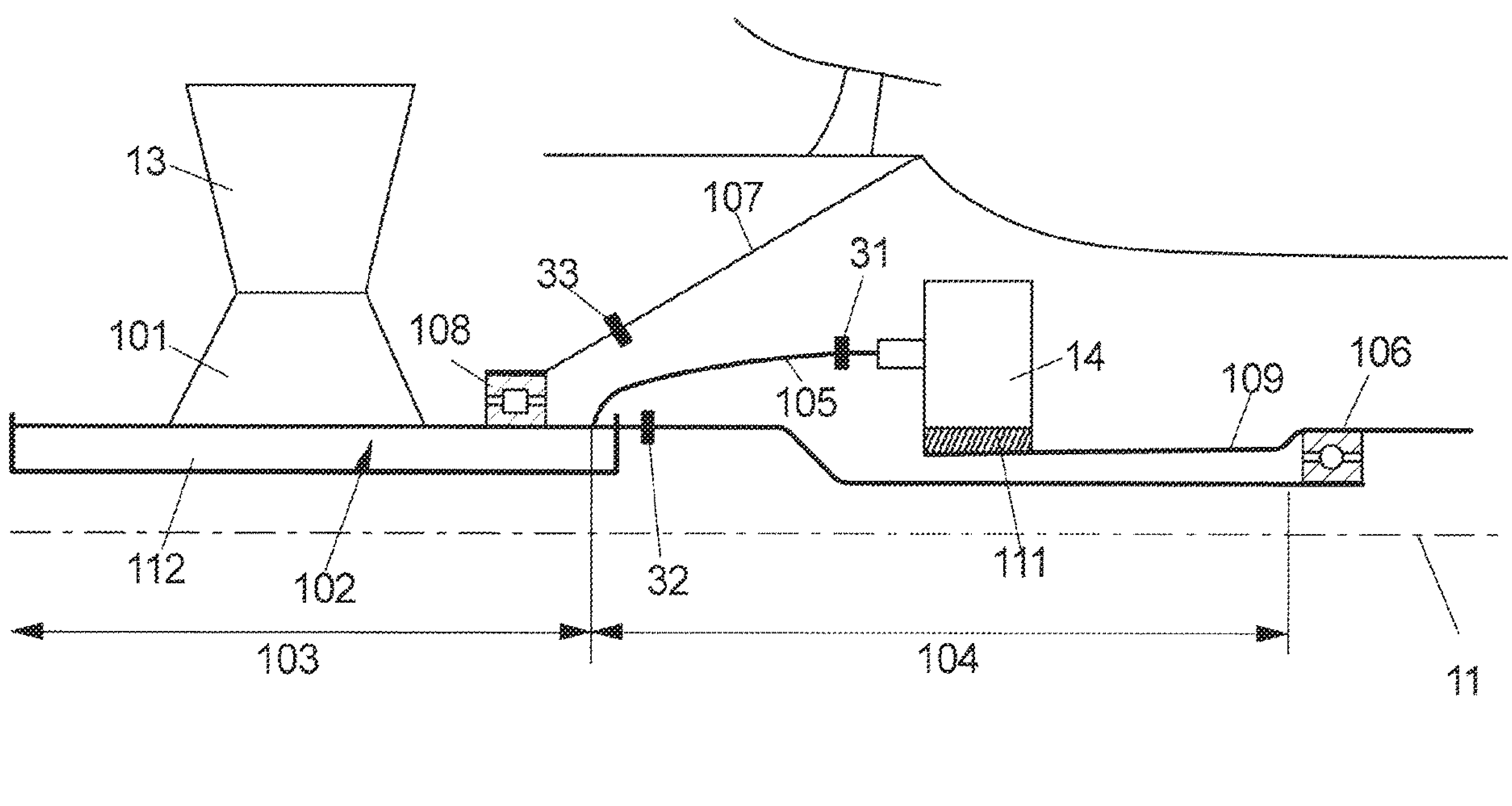
European Search Report dated Mar. 30, 2017 for related European Application No. 16189699.8.
(Continued)

Primary Examiner — Carl C Staubach
(74) *Attorney, Agent, or Firm* — Shuttleworth & Ingersoll, PLC; Timothy J. Klima

(57) **ABSTRACT**

A gas turbine engine with a geared turbofan arrangement with a gearbox in a drive shaft assembly driven by a turbine is provided. A driving side of the gearbox being driveably connected with at least one propulsive fan, with at least one mechanical fuse in the drive shaft assembly enabling a controlled disengagement of at least one engine part from the drive shaft assembly in case of a mechanical failure of the gas turbine engine or a part thereof and at least one load stop for bearing a load, in particular an axial or radial load in case of the mechanical failure of the gas turbine or a part thereof. A first mechanical fuse is positioned in a torque carrying shaft or a torque carrying part of a shaft, in particular in a torque bearing coupling between the shaft and the gearbox.

10 Claims, 4 Drawing Sheets



(51) **Int. Cl.**

F02K 3/06	(2006.01)
B64D 35/02	(2006.01)
F01D 15/12	(2006.01)
F01D 21/14	(2006.01)
F02C 7/36	(2006.01)

(52) **U.S. Cl.**
CPC ***F01D 21/14*** (2013.01); ***F02C 7/36*** (2013.01); ***F02K 3/06*** (2013.01); *F05D 2220/32* (2013.01); *F05D 2220/36* (2013.01); *F05D 2260/30* (2013.01); *F05D 2260/311* (2013.01); *F05D 2260/40* (2013.01); *F05D 2260/40311* (2013.01)

(58) **Field of Classification Search**
CPC F05D 2220/32; F05D 2220/36; F05D 2260/30; F05D 2260/311; F05D 2260/40; F05D 2260/40311; F16D 9/06
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

4,452,567	A *	6/1984	Treby	F01D 5/026	415/9
5,533,825	A	7/1996	Stone		
6,428,269	B1 *	8/2002	Boratgis	F01D 21/045	411/2
7,716,914	B2	5/2010	Schilling		
7,882,693	B2	2/2011	Schilling		
8,621,871	B2 *	1/2014	McCune	F01D 21/02	60/204
9,353,690	B2	5/2016	Makulec et al.		
2002/0069637	A1	6/2002	Becquerelle et al.		
2003/0210979	A1 *	11/2003	Doerflein	F01D 21/045	415/1
2004/0006967	A1 *	1/2004	Clark	F01D 21/04	60/223
2005/0193715	A1 *	9/2005	Opper	F01D 21/003	60/39.091
2005/0220384	A1 *	10/2005	Plona	F01D 21/045	384/624
2007/0084183	A1 *	4/2007	Moniz	F01D 21/04	60/204
2008/0098717	A1	5/2008	Orlando et al.		
2008/0120839	A1	5/2008	Schilling		
2010/0132369	A1 *	6/2010	Durocher	F01D 9/065	60/796
2013/0199206	A1 *	8/2013	Cigal	F01D 17/06	60/803
2014/0271135	A1	9/2014	Sheridan et al.		
2016/0130975	A1 *	5/2016	Chilton	F01D 21/045	415/9
2016/0160875	A1	6/2016	Schwarz		
2017/0081973	A1	3/2017	Swift et al.		
2017/0082065	A1	3/2017	Swift et al.		
2017/0175753	A1 *	6/2017	Tan-Kim	F04D 29/054	
2018/0080387	A1 *	3/2018	Boniface	B64D 35/02	

FOREIGN PATENT DOCUMENTS

EP	2360391	A1	8/2011
EP	2415991	A2	2/2012
EP	2535528	A2	12/2012
EP	2884056	A1	6/2015
EP	2998557	A1	3/2016
EP	3121469	A1	1/2017
FR	3022890	A1	1/2016
GB	2487551	A	8/2012

OTHER PUBLICATIONS

European Search Report dated Mar. 24, 2017 for related European Application No. 16189712.9.
European Search Report dated Mar. 16, 2017 for related European Application No. 16189708.7.
European Search Report dated Mar. 23, 2017 from counterpart EP App No. 16189697.2.
Dominic Boniface—U.S. Appl. No. 15/647,953, filed Jul. 12, 2017.
Gideon Venter—U.S. Appl. No. 15/646,775, filed Jul. 11, 2017.
Dominic Boniface—U.S. Appl. No. 15/708,716, filed Sep. 19, 2017.

* cited by examiner

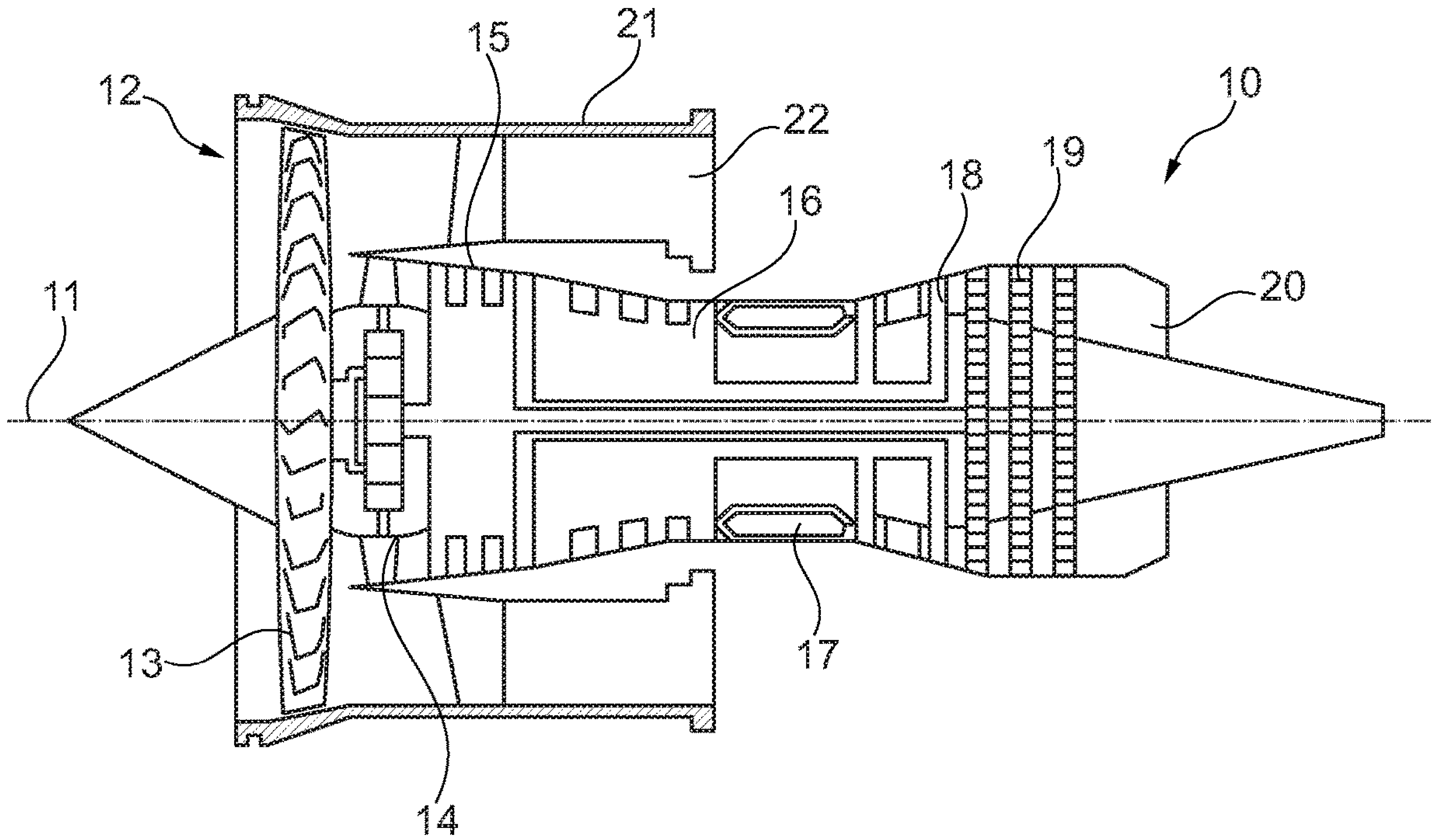


Fig. 1

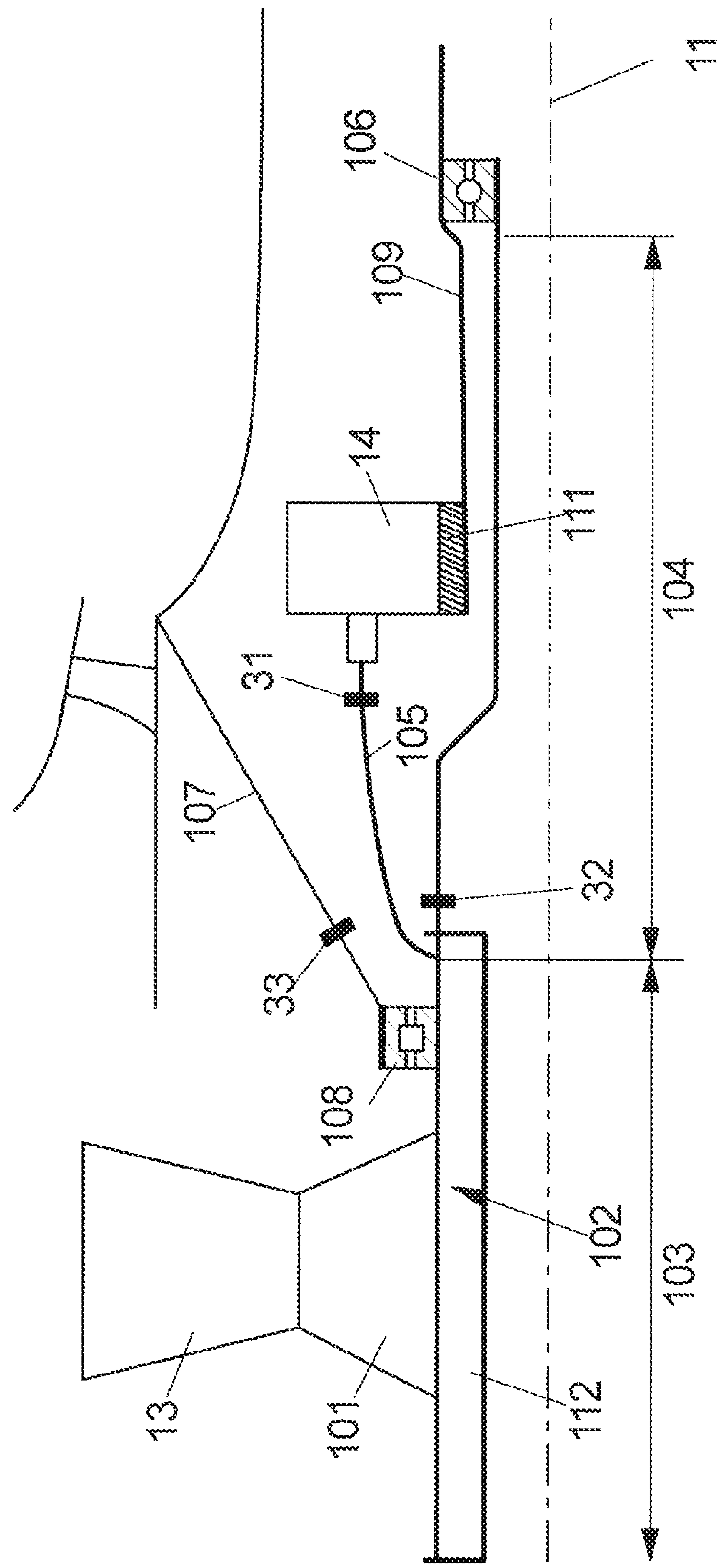
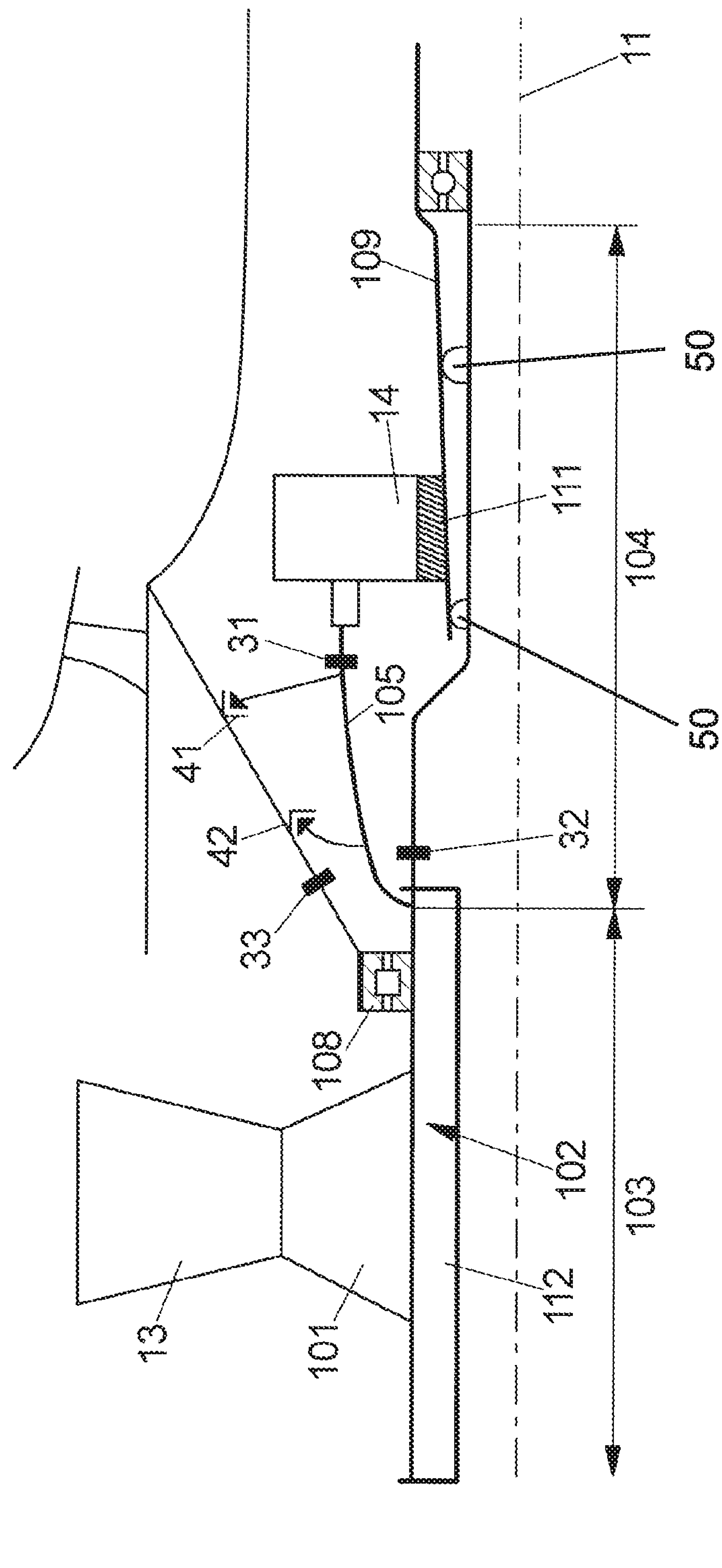


FIG 2

FIG 3



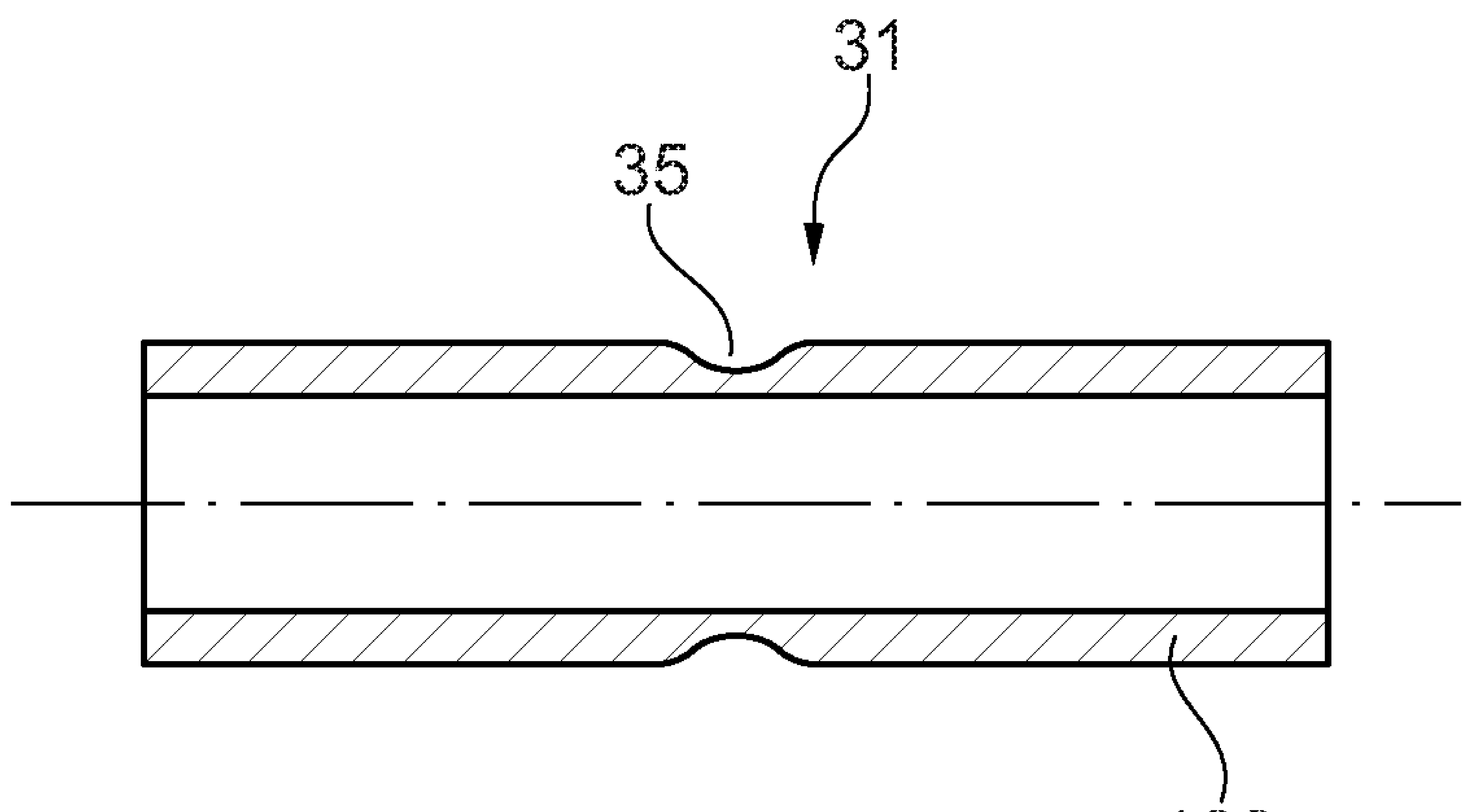


Fig. 4

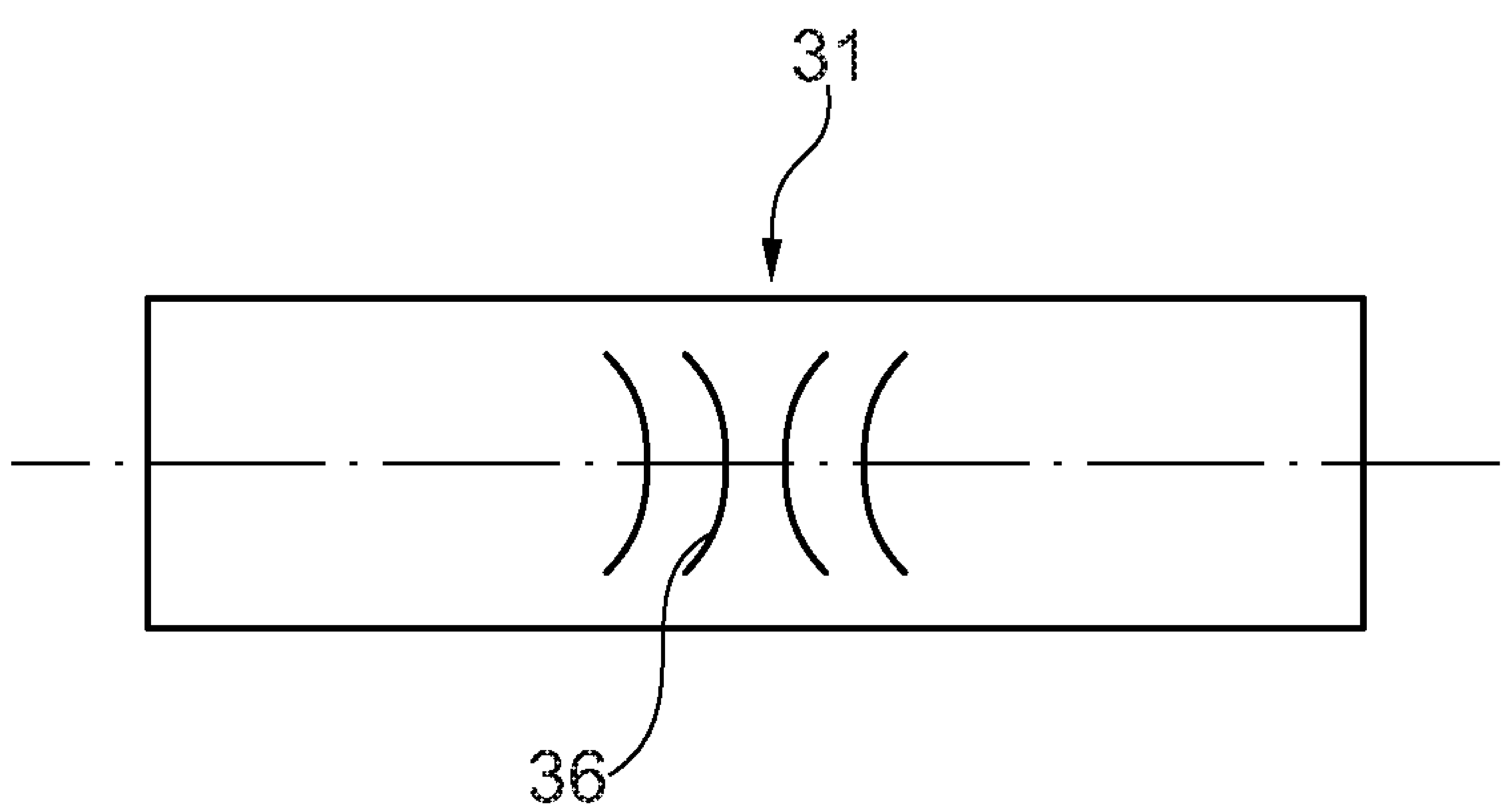


Fig. 5

GAS TURBINE ENGINE WITH A GEARED TURBOFAN ARRANGEMENT

REFERENCE TO RELATED APPLICATION

This application claims priority to European Patent Application No. 16 189 697.2 filed on Sep. 20, 2016, the entirety of which is incorporated by reference herein.

BACKGROUND

The invention relates to a gas turbine engine with a geared turbofan arrangement.

Gas turbine engines with geared turbofan arrangements, in particular aircraft engines, require some means to mitigate damages that might occur after a failure. A failure might involve the rotation prevention of at least one part of the drive train. Such a failure might be e.g. a shaft breaking, a rotor-casing contact or a bearing seizure.

SUMMARY

Therefore, gas turbine engines with an improved resilience are required.

This is addressed by a gas turbine engine with a geared turbofan arrangement with a gearbox in a drive shaft assembly driven by a turbine, a driving side (i.e. the output side) of the gearbox being driveably connected with at least one propulsive fan, with at least one mechanical fuse in the drive shaft assembly enabling a controlled disengagement of at least one engine part from the drive shaft assembly in case of a mechanical failure of the gas turbine engine or a part thereof and at least one load stop for bearing a load, in particular, a radial or axial load in case of the mechanical failure of the gas turbine or a part thereof.

A first mechanical fuse is positioned in a torque carrying shaft or a torque carrying part of a shaft, in particular, a torque bearing coupling between the shaft and the gearbox. The shaft is driveably connected to the gearbox and has a part which carries torque (e.g. a fan shaft) and a part (e.g. a thrust shaft) which essentially only carries bending moments and axial loads. In particular, the first mechanical fuse can comprise a spline joint. The first mechanical fuse will e.g. isolate the gearbox from mechanical damage in case of the mechanical failure.

In an embodiment of the gas turbine engine, the at least one mechanical fuse comprises a defined thinning of a load bearing material, a structuring of a load bearing material and/or a structure with a defined deformable zone. These features of the mechanical fuse alone or in combination allow a defined breakage of the material, forming the mechanical fuse. The strength of the material at the mechanical fuse can be designed so that a load (torque and/or force) beyond a certain threshold will cause a defined breaking at the mechanical fuse location. The mechanical fuse can also comprise a shape of a material which can absorb energy by deforming the mechanical fuse in a defined way.

In a further embodiment, a second mechanical fuse is positioned in a non-torque carrying shaft or a non-torque carrying part of a shaft, in particular the thrust shaft. This mechanical fuse is torque activated.

In another embodiment, a third mechanical fuse is positioned in a front bearing cone of the gas turbine engine, in particular, axially behind a first bearing. The first bearing can e.g. connect the fan shaft with the front bearing cone.

The mechanical fuses are positioned in the gas turbine engine, i.e. the mechanical fuses are coupling two parts or they are embedded with one of the parts. After a certain predetermined threshold value for a force and/or torque is exceeded, the mechanical fuse breaks in the defined way.

In one embodiment, at least one load stop (e.g. a dry bearing) is positioned between a torque carrying part of a shaft, in particular, the torque bearing coupling of the gearbox to the fan shaft to engage a moving part of the gas turbine engine after the mechanical failure. In particular, at least one load stop is designed for retaining the at least one propulsive fan in the gas turbine engine and/or for directing loads away from the gearbox.

To keep the thrust shaft in a secure and rotatable position in one embodiment the thrust shaft comprises and/or is contacting guiding means ("bumpers") to allow rotation under thrust shaft deflection occurring under a failure mode.

Furthermore, it is possible that an embodiment uses detection means for an overspeeding of a shaft, in particular, the thrust shaft. The detection means are usually present in a gas turbine engine for other purposes. The signal regarding an overspeeding can be used to detect a shaft break. Another embodiment comprises a reference shaft for the detection of a shaft break. The rotational speed of the reference shaft is measured. If there is a difference in the rotational speed of a driving shaft, this is an indication that a breakage has occurred.

BRIEF DESCRIPTION OF THE DRAWINGS

Embodiments of the invention are shown in the figures.

FIG. **1** shows a schematic drawing of a gas turbine engine according to the prior art.

FIG. **2** shows a cross-sectional view of a first embodiment of a gas turbine engine.

FIG. **3** shows a cross-sectional view of a second embodiment of a gas turbine engine.

FIG. **4** shows a cross-sectional view of first embodiment of a mechanical fuse in a shaft.

FIG. **5** shows a view of a second embodiment of a mechanical fuse in a shaft.

DETAILED DESCRIPTION

With reference to FIG. **1**, a gas turbine engine is generally indicated at **10**, having a principal and rotational axis **11**. The engine **10** comprises, in axial flow series, an air intake **12**, a propulsive fan **13** (could be more than one stage), a gearbox **14**, an intermediate pressure compressor **15**, a high-pressure compressor **16**, combustion equipment **17**, a high-pressure turbine **18**, an intermediate-pressure turbine **19** and an exhaust nozzle **20**. A fan casing **21** generally surrounds the engine **10** and defines the intake **12**.

The gas turbine engine **10** works in the conventional manner so that air entering the intake **12** is accelerated by the fan **13** to produce two air flows: a first air flow into the intermediate pressure compressor **15** and a second air flow which passes through a bypass duct **22** to provide propulsive thrust. The intermediate pressure compressor **15** compresses the air flow directed into it before delivering that air to the high pressure compressor **16** where further compression takes place.

The compressed air exhausted from the high-pressure compressor **16** is directed into the combustion equipment **17** where it is mixed with fuel and the mixture combusted. The resultant hot combustion products then expand through, and thereby drive the high pressure turbine **18** and intermediate pressure turbine **19** before being exhausted through the nozzle **20** to provide additional propulsive thrust. The high pressure turbine **18** and the intermediate pressure turbine **19**, respectively, drive the high pressure compressor **16** and the intermediate pressure compressor **15**, each by suitable interconnecting shaft assembly.

An intermediate pressure shaft **109** also drives the propulsive fan **13** via the gearbox **14**. The gearbox **14** is a reduction gearbox in that it gears down the rate of rotation of the fan **13** by comparison with the intermediate pressure compressor **15** and intermediate pressure turbine **19**.

The gearbox **14** is an epicyclic planetary gearbox having a static ring gear, rotating and orbiting planet gears supported by a planet carrier and a rotating sun gear.

The embodiment shown in FIG. **1** has a specific shaft arrangement which is understood not to be limiting. The embodiments described in the following can also work with a 2- or 3-shaft arrangement.

As shown in FIG. **1**, geared turbofan engines **10** are known in the art. With increasing power ratings and/or increasing diameters of the propulsive fans **13**, the loads on the gas turbine engines **10** are increasing. Therefore, it seems advisable to introduce measures to counteract potential failure modes or extreme events such as e.g. a fan blade off, a core blade off, a bird strike, a mainline bearing seizure or a gearbox **14** seizure. Some of such failure modes will be described below.

In the following, reference is made to FIGS. **2** and **3** which show different embodiments of gas turbines **10** using mechanical fuses **31**, **32**, **33** (see FIG. **2**) and load stops **41**, **42** (see FIG. **3**) to increase the resilience of the gas turbine **10**.

The counter measures to the failures comprise at least one mechanical fuse **31**, **32**, **33** enabling a controlled disengagement of at least one part of the gas turbine engine **10**, in particular from a drive shaft assembly. The drive shaft assembly comprises e.g. the shafts leading from the turbines **18**, **19** to the compressors **15**, **16** (see FIG. **1**), the gearbox **14** and the propulsive fan **13**. Further details of the drive shaft assembly in the embodiments will be shown below.

In FIGS. **2** and **3** (only one blade partly shown in FIGS. **2** and **3**) the propulsive fan **13** is connected to the output of the gearbox **14** via a shaft **102**, the shaft **102** being a part of the drive part assembly.

The shaft **102** comprises several parts, in particular a fan shaft **103** and a thrust shaft **104**. Furthermore, a torque bearing coupling **105**—also being a part of the shaft **102**—is connecting the shaft **102** with the gearbox **14** at the junction between the fan shaft **103** and the thrust shaft **104**.

The gearbox **14** is only shown schematically in FIGS. **2** and **3** with a sun gear **111** around the thrust shaft **104**.

Under nominal operation the thrust shaft **104** as a part of the shaft **102** does not carry torque, just bending moments and thrust loads. Under nominal operation thrust loads and bending moments are carried by the fan shaft **103**, the thrust shaft **104**, an intershaft bearing **106** eventually to a pylon (not shown in the figures) of the gas turbine engine **10**.

The torque load is transmitted from the gearbox **14** via the dome-shaped torque bearing coupling **105** to the fan shaft **103** to the fan disk **101** and the fan **13**. Therefore, the drive train from gearbox **14** towards the front of the gas turbine engine **10** comprises the torque bearing coupling **105**, the fan shaft **103** and the fan disk **101**. In other embodiments, the torque bearing coupling **105** can have a different shape than the one shown here.

A front bearing cone **107** encloses in particular the gearbox **14** and the toque bearing coupling **105**.

The first mechanical fuse **31** is positioned in or on the torque bearing coupling **105**. This means that it is positioned in a torque carrying part.

The second mechanical fuse **32** is positioned axially just in front of the gearbox **14** in or on the thrust shaft **104**. As mentioned above, the thrust shaft **104** is a non-torque carrying part of the shaft **102**. In general, the second mechanical fuse is positioned in a non-torque carrying shaft or a non-torque carrying part of the shaft **102**, in particular the thrust shaft **104**.

The third mechanical fuse **33** is positioned in or on the front bearing cone **107**, in particular axially behind a first bearing **108**.

A breaking of the first and second fuses **31**, **32** disengages the fan **13** from the gearbox **14** by severing the connections with the torque bearing coupling **105** and the thrust shaft **104**. Therefore, the load due to the failure can be bypassed to other structural parts of the gas turbine engine.

The breaking of the third fuse **33** protects e.g. the engine structure on the gearbox **14**.

In the embodiments shown in FIGS. **2** and **3**, three mechanical fuses **31**, **32**, **33**, i.e. sections in a material which are designed to break under a defined load (torque and/or force, see FIGS. **4** and **5**), are used.

In any case, the material of the torque bearing coupling **105**, the thrust shaft **104** and/or the front bearing cone **107** is locally deliberately thinned and/or structured at the mechanical fuses **31**, **32**, **33** to allow a defined breaking under a defined load.

Furthermore, FIGS. **2** and **3** show a fan catcher **112** which provides a secondary load path between the propulsive fan **13** and the thrust shaft **104**. This provides a retention of the propulsive fan **13** in the event that the fan shaft **102** should fail.

It should be noted that not all embodiments require to have all three mechanical fuses **31**, **32**, **33**. Also, the locations of the mechanical fuses **31**, **32**, **33** might vary due to the application in the gas turbine engine **10**.

In FIG. **3**, two load stops **41**, **42** are schematically shown in addition to the mechanical fuses **31**, **32**, **33**. Regarding the mechanical fuses **31**, **32**, **33** reference can be made to FIG. **2**.

The first load stop **41** comprises an angled structure (one arm pointing in axial direction backwards, one arm pointing radially inwards) mounted or integral with the front bearing cone **107**. Radially inwards a matching structure (one arm pointing in axial direction backwards, one arm pointing radially inwards) is mounted or integral with the torque bearing coupling **105**.

If the first and second mechanical fuses **31**, **32** are broken, the torque bearing coupling **105**—together with the fan shaft **103** and the fan **13**—will experience some radial movement. The angled structure of the first load stop **41** controls the radial and axial movement of those parts because of a form-locking effect when the two parts of the angled structures **41** are moved together after the mechanical failure.

The second load stop **42** also comprises an angled structure. The one part mounted or integral with the front bearing cone **107** has one arm pointing in the axial forward position, one arm pointing in the radial inward direction. The matching structure to this part is mounted or integral with the torque bearing coupling **105**. This second load stop **42** can take an axial load during windmilling situation after the fan **13** has been disengaged from the gearbox **14**.

In the embodiment shown in FIG. **3**, the thrust shaft **104** is contacting guiding means **50** to allow rotation under thrust shaft deflection. The guiding means **50** are e.g. local protrusions or ring-like structures.

In the following, different failure modes are described in particular with reference to FIGS. **2** and **3**. It should be noted that FIGS. **2** and **3** show a number of features which do not have to be present all at the same time.

1. The first failure mode is a failure of the thrust shaft **104** behind the fan catcher **112**. This failure breaks the rear load path which is carrying fan thrust loads and bending moments. If this failure would not be mitigated this would lead to a damage of the gearbox **14** due to additional loads on the torque path and loss of the fan **13** from the gas turbine engine **10**.

In the following, two mitigation options are described.

In the first option, the axial load—which can no longer be carried by the thrust shaft **104**—runs through the torque bearing coupling **105** and causes a breaking in the first mechanical fuse **31**. The first mechanical fuse **31** comprises a defined thinning of the material. Alternatively a spline connection can be used which is subsequently pulled apart due to the propulsive fan **13** thrust loads in axial direction.

In the second option, the increased load causes a seizure of the gearbox **14** which causes a defined breaking of the first mechanical fuse **31**, so that the fan **13** can continue to rotate.

After failure of the thrust shaft **104** and the controlled disconnection through the controlled failure of the first mechanical fuse **31**, the fan **13** will be in windmilling mode with an axial load in the reverse direction.

The second load stop **42**—here a snubber—carries the load produced by the windmilling fan **13**.

2. The second failure mode is a failure (seizure) of the intershaft bearing **106** resulting in a coupling of the input and output speeds of the gearbox **14** or a failure of a component between the fan shaft **103** and an intermediate pressure shaft **109**. In either case the system is subjected to an increased torque.

In one embodiment, a second mechanical fuse **32** is present in the thrust shaft **104** itself, e.g. by a deliberate thinning of the shaft material which breaks in a defined way under a defined high torque event.

After the breaking of this second mechanical fuse **32** the gearbox **14** will continue to rotate. The axial load will go through the torque bearing coupling **105** instead of the thrust shaft **104** resulting in a defined activation of the first mechanical fuse **31**.

As in the first failure mode, after breaking the mechanical fuses **31**, **32** the axial thrust goes through the torque bearing coupling **105** and the first load stop **41** (snubber/dry bearing) into the front bearing cone **107**. As a result, the thrust shaft **104** stops rotating.

The gearbox **14** and the rotor of the intermediate pressure compressor **15** are free of the load from the fan **13**. This results in an overspeed which is detected e.g. by the normal sensors of detecting too fast shaft rotations resulting in an engine shutdown.

As described in the context of the first failure mode, the fan **13** starts windmilling with an axial load in reverse direction which is supported by the second load stop **41**.

3. The third failure mode relates to a gear seizure in the gearbox **14**. This will lead to a stopping of the fan **13** with an increasing powerplant drag.

The rotational momentum of the fan causes a torque spike which will deliberately break the first mechanical fuse **31** in the torque bearing coupling **105**.

4. The fourth failure mode relates to a fan lock. During this event the first mechanical fuse **31** in the torque bearing coupling **105** will break depending on the rotational momentum of the gearbox **14**, the intermediate pressure compressor **15** and the intermediate pressure turbine **19**.

5. The fifth failure mode relates to a fan blade off scenario under which high lateral loads could be transmitted through the first bearing **108** into the front bearing cone **107**, through the fan shaft **103** into the gearbox **14** and through the thrust shaft **104** to the intershaft bearing **106** and beyond.

The thrust shaft **104** deflection under this scenario could cause clashing with the sun gear **111** of the gearbox **14**, leading to sparks, oil fire and failure of the central shaft. The loads may also damage the gearbox **14** and preventing the fan **13** from windmilling.

The first mechanical fuse **31** at the torque bearing coupling **105** could be used to break under a fan blade off condition. The increased out-of-balance loads could be sufficient to break it, especially if the front bearing cone **107** is fused as well. This would not mitigate the thrust shaft **104** clashing risk.

However, if the thrust shaft **104** fails due to the clashing then the fan **13** will be supported by the second load stop **42**. The main issue is that the drive train has been disconnected (i.e. a disconnected torque path) so the gas turbine engine **10** will not run on in a failed state.

The increased thrust shaft **104** loads could also cause seizure of the intershaft bearing **106** or an intermediate pressure thrust bearing.

An increased gearbox **14** load could also lead to a seizure of the gearbox **14** and break the first mechanical fuse **31**.

In some of the failure scenarios windmilling and an axial load reversal will occur. There are two windmilling states:

a) Two mechanical fuses **31**, **32** are broken. In this case, the fan **13** is no longer pulling on the fan shaft **103** and the torque bearing coupling **105**. The load stops **41**, **42** are required to prevent the fan **13** moving aft and tangling with the torque carrier and/or thrust shaft **104**.

b) If only the first mechanical fuse **31** is broken, the thrust shaft **104** carries the axial load during windmill.

It should be considered that the mechanical fuses **31**, **32** should be sufficiently strong under a bird strike. The fusing loads (i.e. the threshold for deliberate failure of the mechanical fuses **31**, **32**) need to be sufficiently high for the other failure modes that the mechanical fuses **31**, **32** do not break under a bird strike alone. The gas turbine engine **10** needs to be able to run on partial power.

In FIGS. **4** and **5**, two different embodiments for a mechanical fuse **31** are shown. FIG. **4** shows a sectional view of a shaft, e.g. the thrust shaft **104**. Circumferentially, a section **35** of the shaft **104** is deliberately thinned. The material strength in this section **35** is so designed that under nominal loads the thrust shaft **104** is operating properly within its design limits. If e.g. a torque exceeds a certain threshold value, the thrust shaft **104** breaks intentionally in the thinned section **35**. A similar design is also possible in parts which are not shaft, e.g. a conical casing or a flat material. The same principle also applies to force loads or combined torque and force loads.

FIG. **5** shows a mechanical fuse **31** which comprises an engraved structure **36** in a material which operates analogue to the thinned section described in connection with FIG. **4**.

The shown designs of the mechanical fuse **31** in FIGS. **4** and **5** are also applicable to the mechanical fuses **32**, **33** in the thrust shaft **104** and/or the front bearing cone **107**.

LIST OF REFERENCE NUMBERS

10 gas turbine engine
11 principal rotational axis

12 air intake
13 propulsive fan
14 gearbox, power gearbox
15 intermediate pressure compressor
16 high-pressure compressor
17 combustion equipment
18 high-pressure turbine
19 intermediate-pressure turbine
20 exhaust nozzle
21 fan casing
22 by-pass duct
31 first mechanical fuse
32 second mechanical fuse
33 third mechanical fuse
35 thinning in a material for a mechanical fuse
36 structuring in a material for a mechanical fuse
41 first load stop
42 second load stop
50 guiding means (bumpers)
101 fan disk
102 shaft
103 fan shaft
104 thrust shaft
105 torque bearing coupling of gearbox to shaft
106 intershaft bearing
107 front bearing cone
108 first bearing
109 intermediate pressure shaft
111 sun gear of power gearbox
112 fan catcher

The invention claimed is:

1. A gas turbine engine with a geared turbofan arrangement with a gearbox in a drive shaft assembly driven by a turbine,

the drive shaft assembly comprising a shaft connecting a propulsive fan to a driving side of the gearbox, the shaft comprising:

a torque bearing portion including a fan shaft and a torque bearing coupling,

a thrust shaft, the thrust shaft being connected to the fan shaft,

wherein the torque bearing coupling connects the fan shaft with the driving side of the gearbox at a junction of the fan shaft and the thrust shaft,

at least one mechanical fuse in the drive shaft assembly enabling a controlled disengagement of at least one engine part from the drive shaft assembly in case of a mechanical failure of the gas turbine engine or a part thereof,

at least one load stop for bearing a load and for retaining the at least one propulsive fan in the gas turbine engine in the case of the mechanical failure of the gas turbine or the part thereof, the at least one load stop operatively positioned between the driving side of the gearbox and the propulsive fan,

wherein the at least one mechanical fuse includes a first mechanical fuse positioned in at least one chosen from the fan shaft and the torque bearing coupling.

2. The gas turbine engine according to claim **1**, wherein the at least one mechanical fuse comprises at least one chosen from a defined thinning, a structuring of a load bearing material, and a structure with a defined deformable zone.

3. The gas turbine engine according to claim **1**, wherein the first mechanical fuse comprises a spline joint.

4. The gas turbine engine according to claim **1**, wherein the thrust shaft forms at least part of a non-torque bearing portion of the shaft, and the at least one mechanical fuse includes a second mechanical fuse positioned in the thrust shaft.

5. The gas turbine engine according to claim **4**, wherein the at least one mechanical fuse includes a third mechanical fuse positioned in a front bearing cone.

6. The gas turbine engine according to claim **1**, wherein the at least one load stop is positioned to engage a moving part of the gas turbine engine after the mechanical failure.

7. The gas turbine engine according to claim **1**, wherein the at least one load stop is configured for directing loads away from the gearbox.

8. The gas turbine engine according to claim **1**, and further comprising a guiding surface at least one chosen from 1) attached to the thrust shaft and engaging other structure of the engine and 2) engaging the thrust shaft, to allow rotation of the thrust shaft under thrust shaft deflection.

9. The gas turbine engine according to claim **1**, and further comprising a reference shaft for detection of a break in the shaft.

10. The gas turbine engine according to claim **5**, wherein the third mechanical fuse is positioned in a front bearing cone axially behind a first bearing.

* * * * *